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XXXVIII. *A Description of some Thermometers for particular Uses. By the Right Honourable the Lord Charles Cavendish, V. P. R. S.*

Read June 30, 1757. **T**HE thermometer (TAB. XI. *fig. 1.*) is designed for shewing the greatest degree of heat, which happens in any place during the absence of the observer. It consists of a cylinder of glass joined to a tube, and differs from common thermometers only in having the top of the stem drawn out into a capillary tube, which enters into a glass ball C, joined on to the stem at the place where it begins to be contracted. The cylinder, and part of the tube, are filled with mercury; the top of which shews the common degrees of heat as usual. The upper part of the tube above the mercury is filled with spirit of wine, and some of the same liquor is left in the ball C, so as to fill it almost up to the top of the capillary tube.

Now when the thermometer rises, the spirit of wine will be driven out of the tube, and will fall into the ball C. When the thermometer sinks again, as the spirit cannot return back from the ball, the top of the tube will remain empty, and the length of the empty part will be proportional to the fall of the thermometer. Therefore, by means of a proper scale, the top of the spirit of wine will shew how many degrees it has been higher than when observed; which being added to the present height, will give the greatest degree of heat it has been at.

C *Fig. 1.*

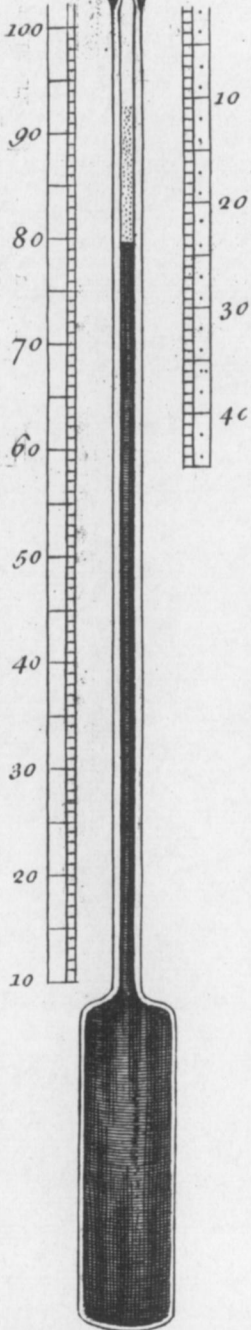


Fig. 2.

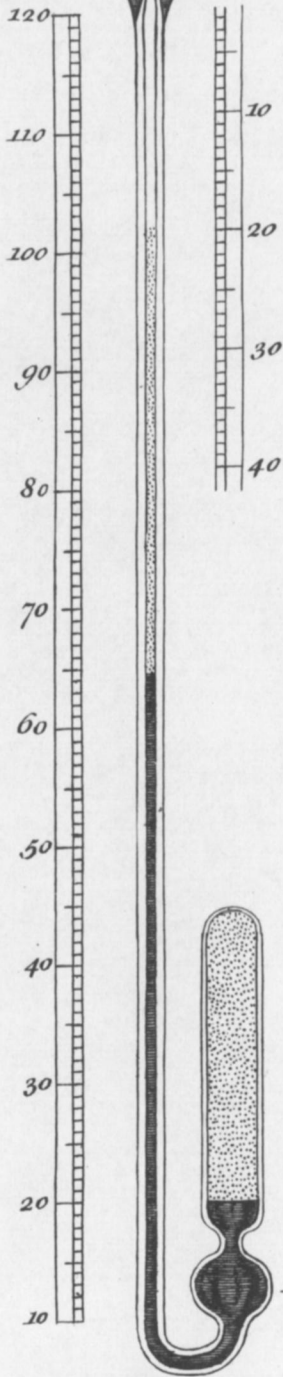


Fig. 3.

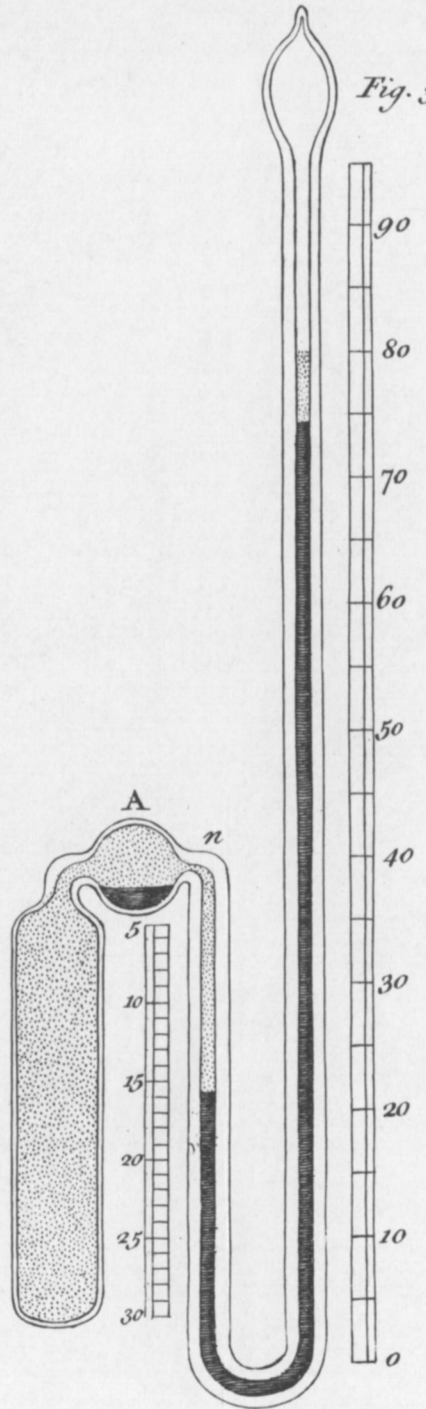


Fig. 2.

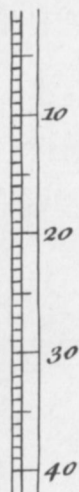


Fig. 3.

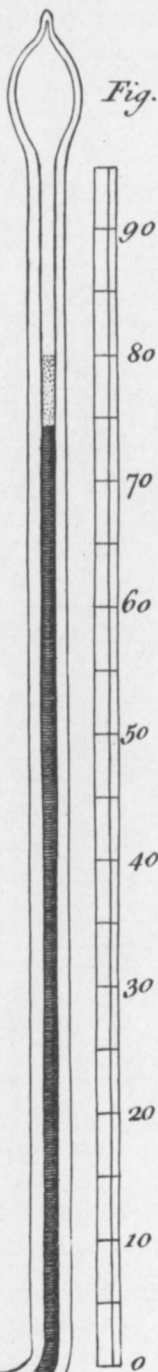
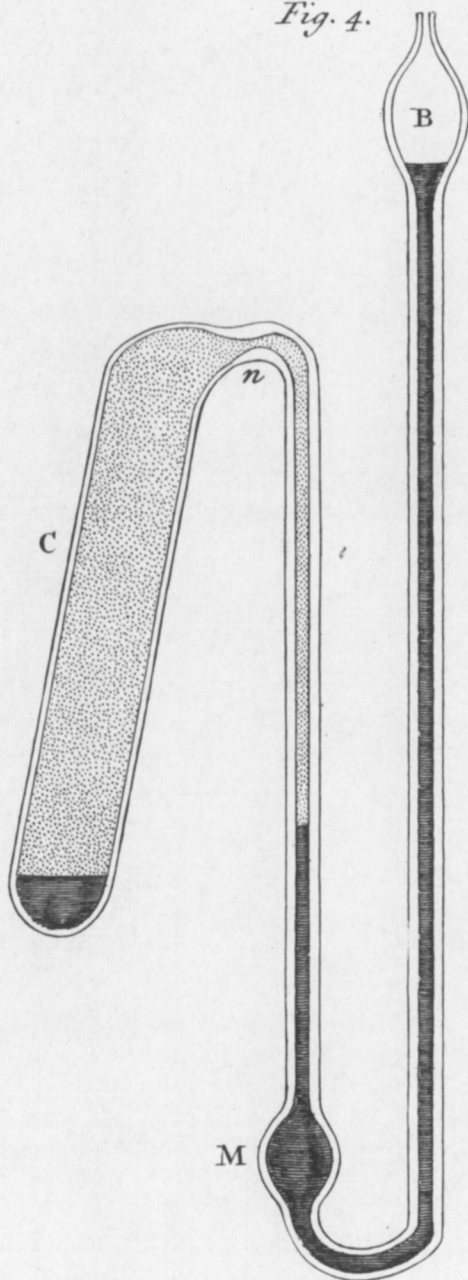


Fig. 4.



To fit this thermometer for a new observation, it is necessary to fill the upper part of the tube with spirits ; which may be done, by inclining the instrument till the spirits in the ball C cover the end of the capillary tube. For if the cylinder is then heated, by applying the hand to it, or by the flame of a lamp held at some distance, till the spirits rise to the top of the tube and run over into the ball C, and is then suffered to cool in the same position, the tube will remain full of spirits, and the thermometer will be fitted for a new experiment.

The top of the capillary tube is made to stand pretty near to one side of the ball, and also to the top of it, that a less inclination of the instrument may be sufficient to make the spirit of wine in the ball cover the end of the tube.

The ball C is joined on as high as possible, so as to hide no part of the tube, except that, where the bore is contracted. By this means, the top of the spirit of wine begins to appear before the thermometer has sunk one degree.

It will be convenient to leave some mercury in the ball C, which may be made to cover the end of the capillary tube, by inclining the thermometer more than what is necessary to make the spirit of wine cover it. By this means some mercury may be got back into the tube, in case any of it should happen to be driven into the ball by the thermometer's being exposed to too great a heat.

The scale of degrees at top, which shews the descent of the thermometer from the highest point it has arrived at, ought not, in strictness, to be the same at all times of the year ; for those degrees exceed
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the common degrees of heat pointed out by the top of the mercury, as much as the column of spirit of wine expands, and therefore are greatest when that column is so; that is to say, when the greatest heat to which the instrument has been exposed is least. A difference of 30 degrees of Fahrenheit's scale, in the greatest rise of the thermometer, would require the scale to be altered one sixtieth part: and the error arising from making use of the same scale will be about one sixth of a degree, if the thermometer is observed when it has fallen ten degrees.

In the instrument here described, the bore of the tube is about 0.027 inches; and one inch of it contains two grains of mercury, and answers to about ten degrees, the cylinder containing about 2280 grains. If a much shorter tube was made use of, a considerable error might arise from too great a quantity of spirits adhering to the sides of the tube, in that part, which is filled with mercury; especially when the thermometer rises fast. This makes it necessary to employ a cylinder of a considerable bigness, if it is desired to have the scale of degrees pretty large.

If the weight of the mercury is thought inconvenient, it may be avoided by the construction described in fig. 2. where the bottom of the tube is bent so as to point upwards, and is joined to a ball A, which communicates with a cylinder placed above it. In all other respects it is the same as the instrument before described.

It is filled with spirit of wine and mercury; the quantity of the latter being sufficient to fill the whole tube and the ball A.

No part of the spirit, with which the cylinder is filled, can get into the tube, as long as the instrument is kept in an erect position, or even if it is carefully laid down flat on a table. For tho' in this last case some of the spirits may get into the ball A, it will rise to that part of the ball, which is then uppermost, and will not touch the orifice of the tube *n*; which was the reason for adding this ball, which would be unnecessary, if the instrument was kept constantly erect, or nearly so. If the spirit should come to touch the orifice of the tube *n*, it would work up between the mercury and the glass; which would put the instrument out of order.

The thermometer fig. 3. is designed for shewing the greatest cold, which happens in any place during the time the instrument is left in it. The tube is bent into the shape of a syphon of unequal legs standing parallel to one another, the bend being at the bottom. The top of the shorter leg is bent to a right angle, and immediately opens into a ball A, which, by means of a short bent tube on the opposite side, communicates with a cylinder standing parallel to the legs of the syphon, and pointing downwards. This cylinder contains the greatest part of the fluid; and is added only to make the thermometer more sensible than it would be, if the ball A was made of a sufficient bigness to contain the proper quantity of fluid. This instrument is filled with spirit of wine, with the addition of as much mercury as is sufficient to fill both legs of the syphon, and about a fourth or fifth part of the ball A.

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The common degrees of heat are shown by the top of the mercury in the longest leg, or by the top of the spirit, in case any of it is left above the mercury.

When the mercury in the longest leg sinks by cold, that in the shorter leg will rise, and will run over into the ball A ; from whence it cannot return back when the thermometer rises again, as the surface of the mercury in the ball is below the orifice of the tube *n*. Therefore the upper part of the shorter leg will be filled with a column of spirits of a length proportional to the increase of heat ; the bottom of which, by means of a proper scale, will show how much the thermometer has been lower than it then is ; which being subtracted from the present height, will give the lowest point that it has been at.

If no further contrivance was used, the mercury would fall into the ball A in large drops ; which would make the instrument less accurate. For the thermometer's beginning to rise immediately after a drop is fallen, or just as it is going to fall (in which case it will return back into the tube), will make a difference of such part of a degree nearly as that drop answers to. To prevent this inconvenience, the top of the shorter leg, close to the ball, is contracted, by being held in the flame of a lamp ; and the passage is further streightened by a solid thread of glass placed within the tube, and extending from the bottom of the shorter leg to the part near the ball A, where it is most contracted. By this means, as soon as any small portion of mercury is got beyond the end of the thread of glass, it breaks off, and falls into the ball

ball in very small drops. This thread of glass is fastened by the heat given to the tube in making the bend next to the ball. In order to fill the shorter leg with mercury, to fit the instrument for a new experiment, it must be inclined till the mercury in the ball covers the orifice of the tube *n*. The cylinder being then heated, the mercury will be forced into the shorter leg, and will run down the thread of glass in drops, which will soon unite. By this means, such a quantity of mercury must be got into the shorter leg, as, upon the cooling of the instrument, will be sufficient to drive all the spirit of wine into the ball with a less degree of cold than what the thermometer is likely to be exposed to.

The ball *A* must always have some mercury in it, but never enough to fill it up to the orifice of the tube *n*. It must therefore be made of such a size, as to contain all the mercury, which can come into it from the tube without being too full. If it should happen to be made too small, so as to be too full in cold weather, any part of the mercury may easily be driven into the cylinder, and got back again into the ball when wanted in warmer weather.

It will be better to leave a little of the spirit above the mercury in the longest leg; in which case the top of the spirit will shew the common degrees of heat. For the filling the tube, so as to leave none, is attended with some trouble; and more of it will be apt to get up there, if the instrument should happen to be held in an improper situation, or if it be kept in too warm a place without filling the shorter leg with mercury by the method above described. If too great a quantity should get up, tho' it would

not affect the scale for the common degrees of heat, it would however cause some error in the degrees on the shorter leg; inasmuch as the expansion of that portion of spirits, which has got up into the longer leg, exceeds the expansion of the mercury, which must supply its place. It may be got back at pleasure, by exposing the thermometer to such a degree of cold as will make the spirit get beyond the bend of the syphon; for then it will run up along the thread of glass in the shorter leg till it gets above the mercury there. For this purpose the point of 0 degrees of Fahrenheit's scale should be near the bend; by which means, any part of the spirit of wine may be got beyond it by an artificial cold; and there will be no danger of the whole getting beyond it by any natural cold; in which case the air would get up into the ball.

The scale of degrees on the shorter leg will, in different seasons, be liable to an error of the same kind as that, which was explained in the first-mentioned thermometer; but in this it will be less considerable, as the space between the two scales is filled with mercury, whose expansion is about six times less than that of spirit of wine.

In the thermometer, which I have, the bore of the tube is about 0.054 inches; and one inch of it contains eight grains of mercury, and answers to seven degrees of Fahrenheit's scale. The drops of mercury, which fall into the ball A, answer to about one eighth of a degree.

If instruments of the nature of those above described, were to be used for finding the temper of
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the sea at great depths, some alteration would be necessary in the construction of them, principally upon account of the great pressure of the water; the ill effect of which can, I believe, be prevented no other way, than by leaving the tube open. For if the thermometer was made strong enough to resist the pressure without breaking, yet it would be impossible to be sure, that the figure of the glass would not thereby be altered, which should make the experiment uncertain.

The instrument for finding the greatest heat might be made just like that of fig. 1. only leaving the top open. It is to be filled with mercury only, as is also the lower part of the ball at top, but not near so high as the end of the capillary tube. The upper part of that ball, being left open, will in a great measure be filled with the sea-water, which will be forced into it by the pressure.

If this instrument (the tube being quite full of mercury) is plunged into any part of the sea, where the heat is greater than that of the air above, part of the mercury will be driven out of the tube; and, upon bringing it into a colder place, the sea-water or air in the ball will enter into the tube, and will fill the space left by the mercury.

As this thermometer does not show the common degrees of heat, it must be placed in a vessel of water with another thermometer, and the scale of degrees at top will shew how much the heat it has been exposed to is greater than that of the water in the vessel.

The sea-water getting into the glass will corrode the mercury, and thereby foul the glass; which

will make the experiment less exact : and therefore it would be much more convenient, if the sea-water could intirely be kept out ; which probably may be done by tying a bladder full of air to the neck of the ball C, which will contract by the pressure of the water, without letting any of it get in.

If this can be done, the instrument may be filled with mercury and spirits, just like that at fig. 1. But it would be more convenient to fill it with mercury only : in which case it may be made with as small a tube and ball as common mercurial thermometers : or it may be filled with spirits only. The instrument will thereby become much less bulky ; which will compensate the want of the common scale of heat.

It is better to put but little mercury into the ball at top, for fear of its getting into the capillary tube by the motion of the instrument.

The thermometer for finding the greatest cold, if applied to this purpose, must also be left open at top. There is another inconvenience to be avoided ; which is, that the mercury in the ball A, by the tossing of the instrument, might sometimes get into the shorter leg of the syphon ; which would spoil the experiment. To prevent such an accident, the most convenient construction, which occurs to me, is that of fig. 4. which differs from fig. 3. in having the ball A omitted ; so that the mercury running out of the shorter leg will fall to the bottom of the cylinder, and will not be so liable to get back into the tube by motion. The cylinder is made to stand not quite parallel to the legs of the syphon, that the mercury contained therein may more easily be brought to touch

touch the end of the tube, in order to fit the instrument for a new experiment.

If, by means of a bladder, the sea-water can be kept out of the glass, this instrument may be made to shew the common degrees of heat; but even then, in order to render it less bulky, it may be better to supply the want of them as in the last instrument. The longer leg of the syphon may in that case be made as short as you please; only making the ball B big enough to receive all the mercury, which may be driven into it by heat.

If thermometers of this kind were to be sent up into the air by means of a kite, they might be made like those proposed for the sea; but it would not be necessary to leave them open.

As it would be desirable to make them as small as possible, they should be made so as not to shew the common degrees of heat: and it would also, on that account, be convenient to omit the thread of glass placed within the shorter leg of the syphon in fig. 3. and 4. This thread of glass is placed there in order to make the mercury fall into the ball A. fig. 3. or cylinder C. fig. 4. in smaller drops, and also to facilitate the filling the shorter leg with mercury. The latter purpose may be answered by having a ball blown towards the bottom of the shorter leg, as marked in fig. 4. at M: for as soon as the mercury driven out of the cylinder by heat gets to that ball, it will pass by the spirit of wine. The other purpose may probably be answered by having the tube contracted as much as possible at *n*.

In the foregoing instruments the tubes made use of were of a large bore, as most of the errors in them.

them would increase by making use of smaller ones. Possibly less ones might be used without much inconvenience. The chief advantage will be, the making these thermometers more sensible of the changes of heat, than when large cylinders are used. This will be of service when the greatest degree of heat or cold continues but a short time.

It is better to use plain spirit of wine, than what is tinged, which seems more apt to cause a foulness in the tube, and thereby makes the surface of the mercury less well defined. I am induced to believe so, from observing, that the portion of spirits above the mercury in the tube fig. 3. which at first was strongly tinged with cochineal, in some months became perfectly colourless, the tinging particles being deposited in different parts of the tube, and causing a foulness there. The colour of the spirits in the cylinder does not appear to be altered.

The dark-shaded part in the several figures represents mercury, the dotted part spirit of wine.